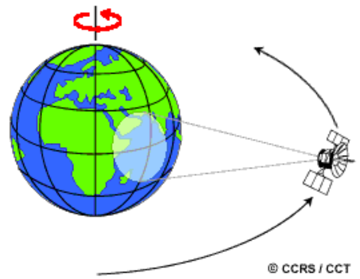
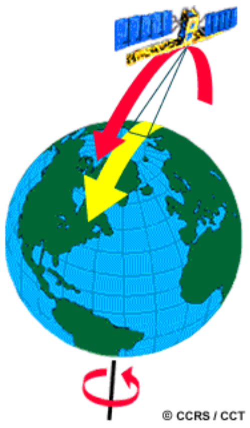
NOS hydrology use case examples

February 2020

Motivation

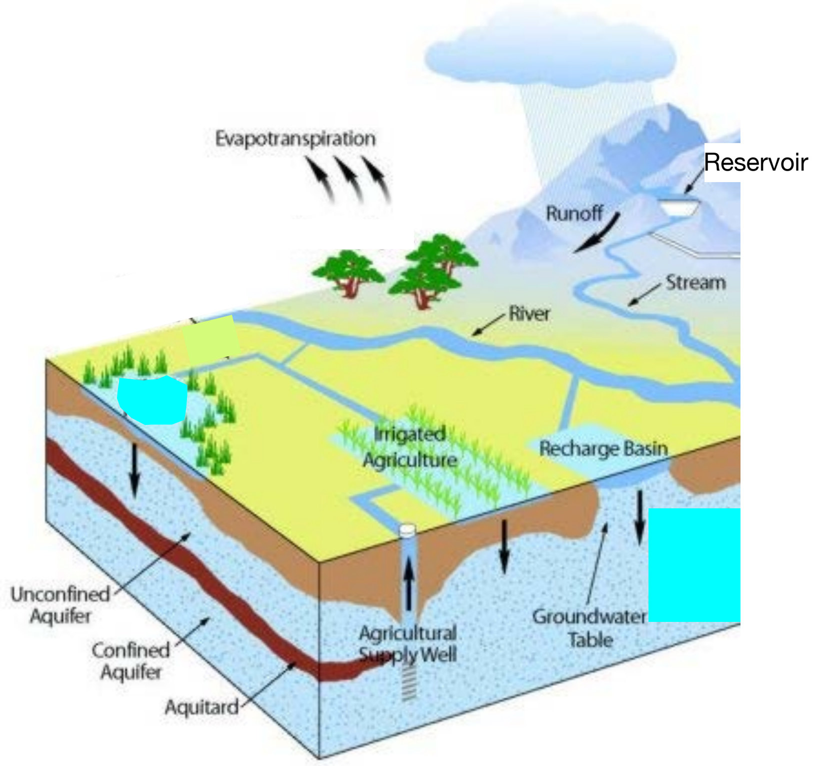
- There has been tremendous advances in land remote sensing in the past three decades (global measurements of precipitation, soil moisture, snow cover, terrestrial water storage are available)
  - Variables such as evaporation, snow water equivalent, ground water, water quality are still hard to measure (no single appropriate technology exists)
  - Interpretation challenges: How to convert from radiance measurements to geophysical quantities?
- Engineering/operational constraints
  - High temporal resolution implies that the satellite must be in high altitudes (geostationary); lower altitude satellites orbit in polar orbits, with coarser revisit times
  - Constellations can improve the temporal resolution; challenges in the development of coordinated multi-platform observing systems.
- Focus on single measurements:
  - Water cycle is a connected system, scientific community is often focused on ‘single sensors/single geophysical variable’ approach
  - Danger of mission/instrument failures (SMAP, Landsat 6, OCO)
- Evaluation infrastructure
  - Decline of ground networks, measurements





Specific hydrology examples

- Precipitation
  - Measured by GPM constellation (at 30mn interval) with microwave instruments
  - Resolution is essentially limited to ~5km
  - Coverage is insufficient over high latitudes
  - Ground-based radars have poor coverage over mountains
- Evaporation
  - Second largest hydrological flux, yet no direct remote sensing measurement available
  - Significant indicator of human management (e.g. agriculture)
- Soil moisture
  - Microwave instrument-based resolution is coarse, not sufficient for field scale applications
  - Ground-based measurements have poor coverage; inconsistent with satellite and model estimates
- Runoff
  - Most important for water management; difficult to measure from space.
  - Radar altimeters will provide estimates of river height, but models are needed to convert them to streamflow
- Snow
  - Passive microwave retrievals of SWE are limited to dry and shallow snowpacks; SAR approaches being considered for wet snow; no direct approaches exist for permafrost
- Groundwater
  - Gravity sensors can provide estimates of terrestrial water storage; Models are needed to separate the components
  - Coarse temporal and spatial resolution
- Vegetation
  - Optical sensors can provide vegetation estimates, affected by cloud gaps
  - Indirect measurements (“signals of opportunity”) from microwave (vegetation optical depth) and optical spectrometer (solar induced fluorescence)



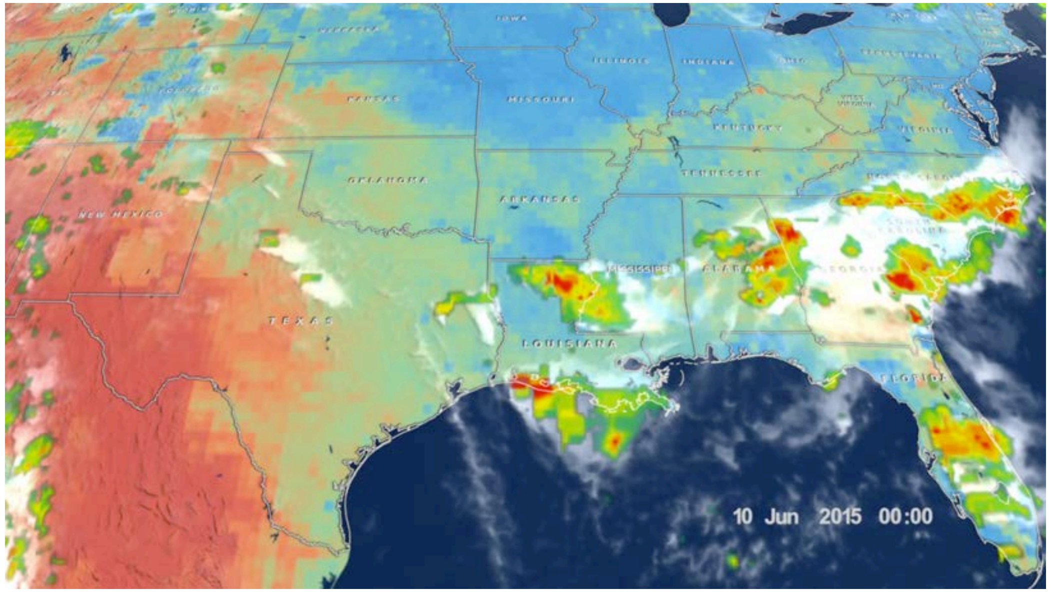
Use case examples

Example 1: Fire/Mudslide events

A fire event can dramatically alter the landscape through significant changes to the vegetation. The removal of the vegetation can weaken the rooting structures. If heavy precipitation events follow fire events, the lack of transpiration (due to the lack of roots) can lead to increased runoff, which can trigger mudslide and landslide hazards (e.g. California mudslides in 2018)

1. Optical space sensor measurements (LAI/NDVI) capture potential vegetation disturbances from fire.
2. Model-based runs are used to confirm this ‘anomaly detection’ (Comparison with a model run that only simulates impacts of natural variability/seasonality will enable the rapid detection of these anomalous features).
3. This triggers active and passive microwave sensors (from distributed spacecrafts, airborne platforms) and possible ground sensors to measure precipitation and soil moisture conditions at high frequency (hourly).
4. When microwave sensors detect anomalous wet conditions, they trigger ground sensors to sense river runoff.
5. Assimilate the distributed sensor data to evaluate/confirm the utility of information.

Use case examples



Brown ocean:

Brown ocean effects represent the intensification or sustenance of tropical cyclones after landfall due to the availability of sufficient moisture over land. This can happen if the antecedent soil moisture conditions are wet enough as the cyclone makes landfall..

1. Microwave/IR sensors will provide estimates of an approaching hurricane or typhoon about to make landfall.
2. This triggers space-borne microwave instruments (airborne, distributed spacecrafts) and ground-based networks to infer soil moisture at a high frequency (hourly) to develop estimates of antecedent soil moisture.
3. These information will be continuously fed into a regional model to make forecasts about the track and sustenance of the storm post-landfall.

Use case examples

Depletion of water resources from elevation dependent warming:

The loss of snowpack from generalized warming leads to decreased snow albedo, increased absorption of solar radiation and increased snow melt. As climate warms, increased snow melt and retreating snowlines upslope lead to a positive snow albedo feedback that can amplify the snowmelt and depletion of water resources.

1. Optical sensors from reflectance measurements will infer anomalous reductions in snow albedo concurrent with warmer land surface temperature changes at high elevation terrain. Model outputs combined with remote sensing outputs can be used for this purpose.

2. This triggers measurements of vegetation changes (from optical sensors) and snow water equivalent (from microwave instruments) over the lower and mi—elevation terrain to infer the upslope migration of tree lines and changes in snow melt.

3. The anomaly detection from reflectance measurements will trigger ground sensors to measure river flow and changes in the timing of snow melt.

Use case examples

Fires at high elevations/Snow Evolution:

Fires at higher elevations can also remove forest cover which affects the snow evolution. Soot deposited on the snow can speed up melting and can lead to flooding events. The earlier than usual melt can deplete the amount of resources available in the spring season and lead to droughts.

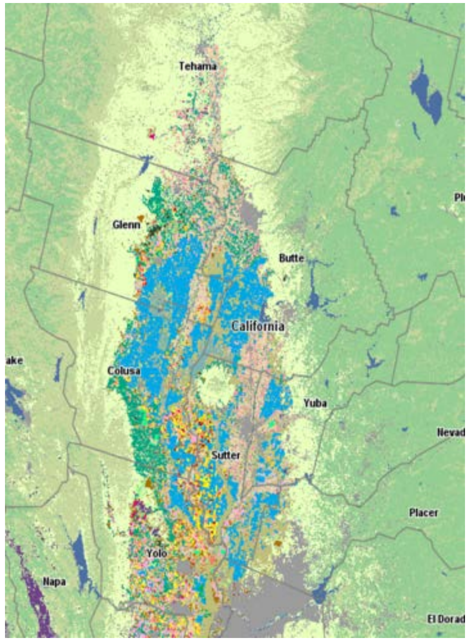
1. Optical space sensors detect potential vegetation disturbances from fire or aerosol anomalies from pollution.
2. Model-based runs are used to confirm the disturbances (Comparison with a model run that only simulates impacts of natural variability/seasonality will enable the rapid detection of these anomalous features).
3. These changes trigger additional monitoring of optical reflectance (to infer albedo and snow cover) and passive microwave (to infer snow water equivalent) space measurements, in the next several months.
4. The detection of albedo/snow cover or Snow Water Equivalent (SWE) anomalies then triggers the upstream ground sensors to monitor river flow to detect possible flooding from early snow melt.

Use case examples

Anthropogenic agriculture impacts:

Human management activities such as irrigation can significantly influence the moisture state of the surface. The attribution of water, either from surface or groundwater for irrigation, also affects the amount of fresh water resources available. Simultaneous availability of observations can help to quantify and manage water availability.

1. Reflectance measurements from optical space sensors infer impacts of irrigation on the surface (cooler land surface temperature, wetter soil moisture).
2. Land surface model simulations that DO NOT include irrigation features are used jointly with data from optical sensors to infer these anomalous features.
3. Detection of irrigation features:
    a. Triggers (or activates the search for additional date from?) additional sensors to infer more frequent measurements of surface and ground water storages, from altimetry and gravity sensors, respectively.
    b. Triggers ground sensors to measure surface and ground water storage measurements.
4. Together (3a) and (3b) provide estimates of management related water withdrawals.



Use case examples

- **Amplification of heatwaves/drought:**

Deforestation or fires can remove the vegetation cover on the land surface and lead to increased drying of the soil under persistent drought. If vegetation were present, then the stomatal control exerted by the plants would limit the amount of evaporation losses. The surface warming from drought often leads to heatwaves.

1. Optical space sensor measurements (LAI/NDVI) together with model outputs capture vegetation disturbances from fire.
2. The detection of vegetation anomalies triggers the following measurements to diagnose water limited conditions. The simultaneous occurrence of water limited conditions triggering evaporative stress provide indicators of drought onset:
   a. Space-borne microwave and
   b. Ground measurements of soil moisture to diagnose water limited conditions.
3. This also triggers more frequent measurements from TIR sensors for land surface temperature. These measurements will be used to estimate evaporative stress.
4. The detection of drought onset further triggers additional sensors to infer more frequent measurements of surface and ground water storages, from altimetry and gravity sensors, respectively. These measurements will be used to compute surface and ground water withdrawals, expected under drought conditions.

Summary

- H-MIDAS targets the development of a science-driven environments that facilitates new observing strategies
  - Rapid science translation of raw measurements
  - Enable flexible, adaptive measurements driven by modeling systems
  - Enable interoperable data interfaces, non-local data access and open data paradigms
  - Facilitate a framework for the characterization of observational knowledge gaps